

RING DOWN SPECTROSCOPY WITH A BREWSTER'S ANGLE PRISM RESONATOR

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Cavity Ring Down Spectroscopy (CRDS) is an important spectroscopic technique with applications to science, industrial process control, and atmospheric trace gas detection. At present, this method is limited to spectral regions where one can obtain high reflectivity dielectric mirrors, and there, only over spectral tuning ranges of a few percent for a single set of mirrors. To overcome these limitations, we have designed, constructed, and tested an astigmatic prism ring resonator which utilizes total internal reflection to achieve high reflectivity, a curved prism face for optical stability, and reflective coupling near Brewster's angle to provide controlled finesse of the resonator. We have measured the loss of this resonator, which includes scattering, diffraction, and stress induced birefringence, in the range between 470 nm to 1.6 μm and found good agreement with calculated values.

1 Summary

CRDS has its origins in measurements of high quality laser mirror reflectivity² and was first developed for spectroscopy by O'Keefe and Deacon³. The technique consists of measuring the photon decay time of a high quality optical resonator containing weakly absorbing species as a function of frequency. The decay time is inversely proportional to the resonator losses, and since the bare resonator losses can be made small, it is possible to detect extremely weak absorption. The relationship of the decay rate to the absorption can be expressed as, $\gamma = \gamma_{em} + \alpha(\nu)c$, where γ_{em} is the empty resonator decay rate, $\alpha(\nu)$ is the absorption coefficient, and c is the speed of light. The high sensitivity of the technique can be understood in terms of the large effective path length, $l_{eff} = c/\gamma$, which can be many kilometers. Furthermore, the measurement of the decay time is insensitive to laser intensity fluctuations, and both pulsed and cw lasers can be used. In figure 1, the broad tunability of the resonator is exploited with a ps source to demonstrate multiplex spectroscopy of weak O₂ lines in air. With the suprasil prisms, bulk scattering and diffraction are the dominant loss mechanisms aside from coupling which is adjustable with incident angle. Scattering losses can be improved by using single crystal materials such as Al₂O₃, CaF₂, or YAG which we are now in the process of evaluating. Stress induced birefringence was reduced to an ac-

ceptable level through careful mounting of the prisms, and leakage at internal reflection surfaces was found to be insignificant. The minimum loss per pass excluding coupling occurred at 900 nm and was $\approx 7 \times 10^{-5}$, a result due to excessive diffraction as a result of an error in fabrication which we anticipate will be improved significantly in a new prism.

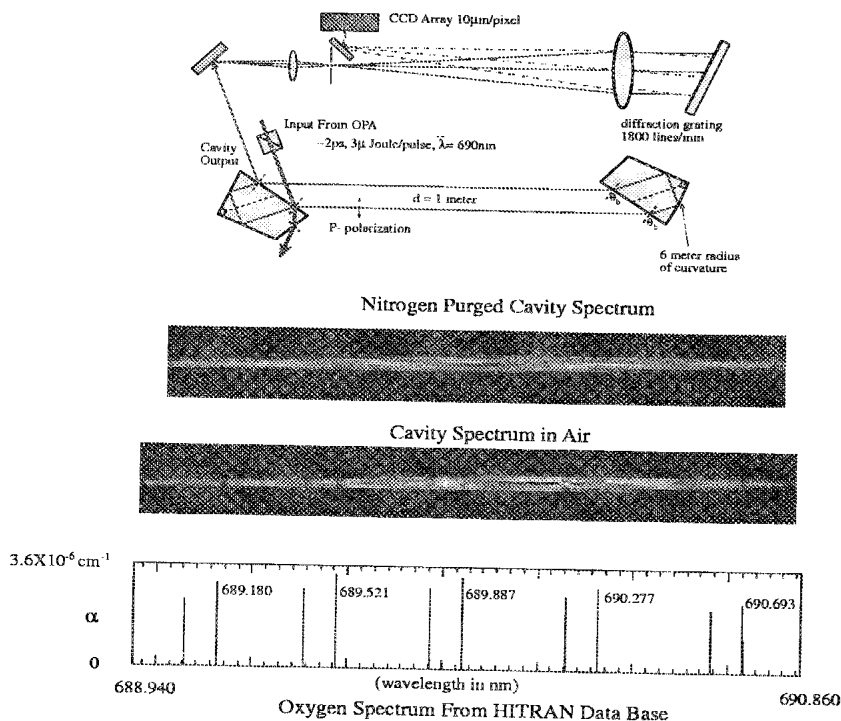


Figure 1. Prism resonator with ps source arranged for multiplex spectroscopy.

References

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